



MaxDepth Aquatics, Inc.

Periphyton in Selected Sites of the Klamath River, California

**Prepared for
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ABSTRACT

A survey was conducted at ten sites in the Klamath River of California in September 2004 to determine the nature of the periphyton communities in the river system. Sample sites were selected to correspond with previous investigations of periphyton in the Klamath River and its tributaries. A similar protocol for sampling at each site was followed in which samples were collected for periphyton community composition, periphyton chlorophyll *a*, periphyton biomass, and nutrient content of the periphyton. The epilithic periphyton was dominated at most sites by diatoms (Bacillariophyceae). One site had significant quantities of *Cladophora* (a filamentous green alga) and one site had moderate quantities of *Calothrix* (a filamentous cyanobacterium). Many of the diatom taxa were indicative of sites with some degree of perturbation. The periphyton populations observed in the September 2004 sampling of the Klamath River system exhibited low biomass and were dominated by taxa typically found in moderately enriched submontane riverine systems. The species composition showed a transition from a *Cocconeis/Diatoma*-dominated community upstream to a system heavily dominated by *Epithemia* downstream. The nutrient concentrations of the periphyton showed large ranges in concentrations, but relatively constant ratios of C:N and N:P, the one major exception being the Scott River where the N:P ratio was four-fold greater than the average river ratio. The high N:P ratio in the Scott River coincided with a totally different periphyton community dominated by *Cymbella affinis*.

INTRODUCTION

Tetra Tech, Inc. was contracted by the U.S. EPA to model spatial and temporal variations in water quality throughout the Klamath River. The mathematical modeling requires that the key physical, chemical, and biological attributes of the system be represented to the extent possible. It was recognized that aquatic plants are abundant in portions of the Klamath River and thus may play an important role in affecting nutrient fluxes and short-term changes in water quality parameters such as dissolved oxygen and pH.

Consequently, Tetra Tech, Inc. contracted with MaxDepth Aquatics, Inc. to sample selected sites in the Klamath River and characterize the periphyton community. This report describes the results of this study.

METHODS

Ten sites were selected for sampling in the Klamath River (Figure 1). These sites were selected to represent portions of the lower Klamath River from Irongate Dam to the confluence with the Trinity River. The final list of sample sites was reviewed by staff from the North Coast Regional Water Quality Control Board and Tetra Tech, Inc. The site locations are depicted in Figure 1 and are listed in Table 1. The locations of the Klamath River mainstem sites with respect to distance from the mouth and elevation are shown in Figure 2.

At each site, digital images were recorded to document the conditions at the time of sampling. At each site, the depth was measured and the current velocity was measured at 60 percent of total depth with a Marsh-McBirney Flo-Mate 3000 current meter. Light reduction was measured by lowering an Onset[®] light intensity meter oriented up and attached to a marked rod into the river. The meter was held in position for two minutes at each depth interval of 0.3 m up to a maximum depth of 0.61 m or the river bottom was reached.

At each position, the percent algae coverage was recorded by placing a 0.25 m² quadrat over the surface and estimating the coverage in each of the 16 subdivisions within the quadrat. The percent coverage was expressed as the average of the percentage cover within each quadrat. Periphyton samples were collected from two quadrats per site (Figure 3). The location of the quadrat frame was positioned to meet the depth, light, and flow velocity criteria prescribed for sampling. Four rocks of comparable size (~ 10 to 15 cm diameter) were collected from within the quadrat frames. Prior to processing, unattached debris was rinsed from each rock. Rocks were lined up on the shore and the different types of periphyton sampling were processed in the same order (from left to right) at each site. The four sample rocks for each site were documented in a digital image (Figure 4). An area corresponding to the size of a standard microscope slide (25

mm X 75 mm) was marked using a pre-cut Delrin[®] template (Figure 5) and scraped from a suitable rock (Figure 6) and placed into a Nalgene[®] jar and preserved with Lugol's solution. A second rock was scraped to achieve sufficient sample size (2-5 g, wet weight) and placed into a WhirlPac[®] bag for elemental analysis. In cases where periphyton coverage or density was too low, multiple rocks (in some cases, up to eight rocks) were scraped for this analysis. A third rock was scraped equivalent to the slide area for analysis of chlorophyll *a*. This sample was placed in a Nalgene bottle with distilled water and magnesium bicarbonate as a preservative. A fourth rock was sampled for the same area and placed into a WhirlPac bag for analysis of ash-free dry weight.

The chlorophyll *a* samples were shipped overnight to Aquatic Analysts, White River, Washington. Chlorophyll *a* was analyzed using a spectrophotometer and phytoplankton community composition was determined by light microscopy. Samples retained for chemical analysis were dried at 65 °C, 105 °C, and 500 °C. The samples were analyzed for carbon and nitrogen on a Leco Analyzer. The plant tissue was also analyzed for phosphorus using a total Kjeldahl digestion followed by spectrophotometric measurement of phosphorus. Details of all field and analytical methods are presented in the quality assurance project plan (Tetra Tech, Inc. 2004).

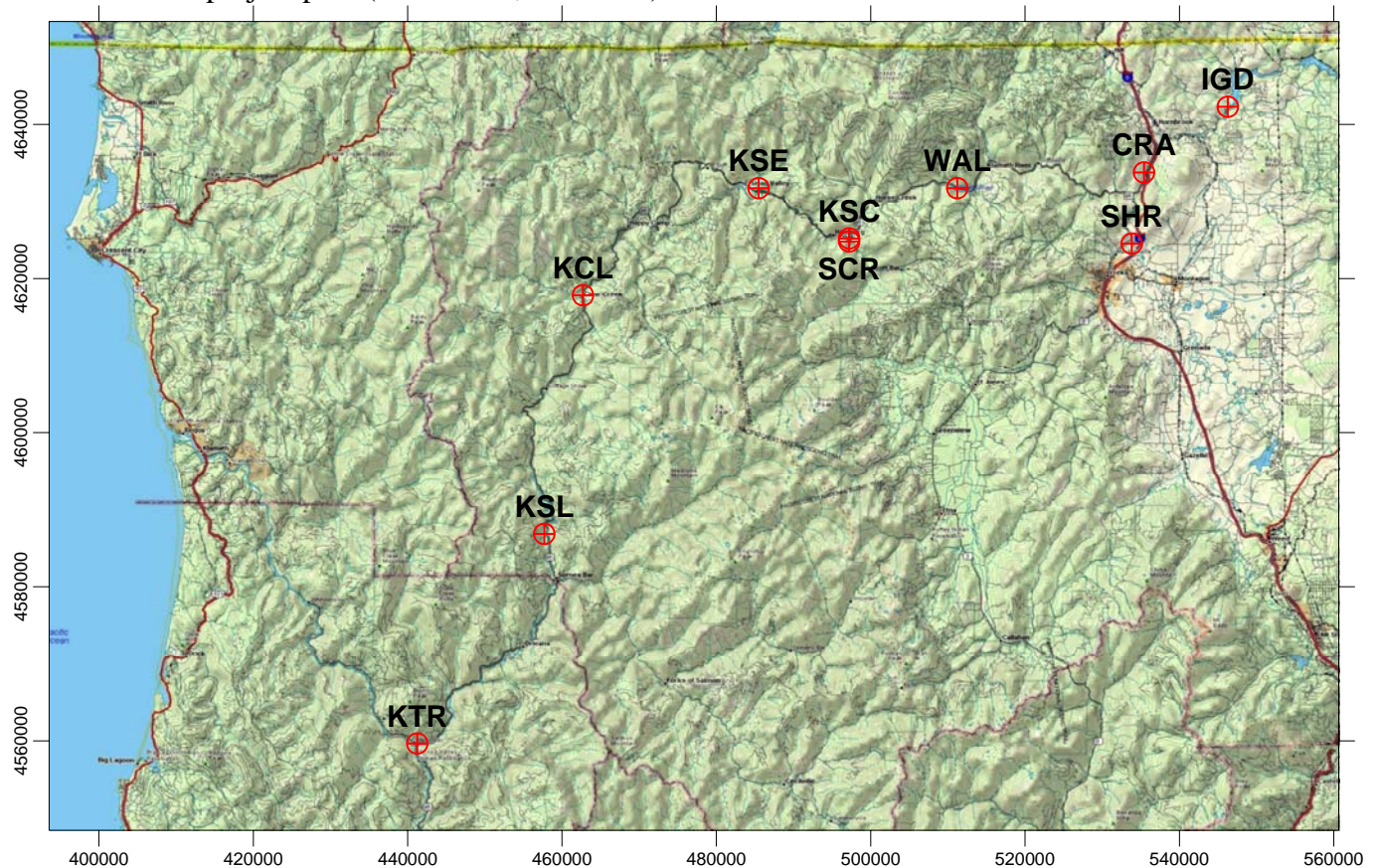


Figure 1. Klamath River system study sites shown in red. The yellow horizontal line represents the border between Oregon and California. The numbers on the axes are UTM coordinates.

Site Name	Site Code	Latitude	Longitude
Iron Gate Dam (tailrace)	IGD	41 55.869	122 26.518
Klamath at Collier Rest Area	CRA	41 51.296	122 34.401
Shasta River ^a	SHR	41 46.312	122 35.581
Klamath at Walker Bridge Rd	WAL	41 50.238	122 51.896
Klamath Above Scott River	KSC	41 46.718	123 02.015
Scott River ^a	SCR	41 46.505	123 02.017
Klamath at Seiad Valley	KSE	41 50.233	123 10.501
Klamath Above Clear Creek	KCL	41 42.679	123 26.889
Klamath Above Salmon River	KSL	41 25.932	123 30.374
Klamath Above Trinity River	KTR	41 11.167	123 42.036

^a Tributary sites to the Klamath River

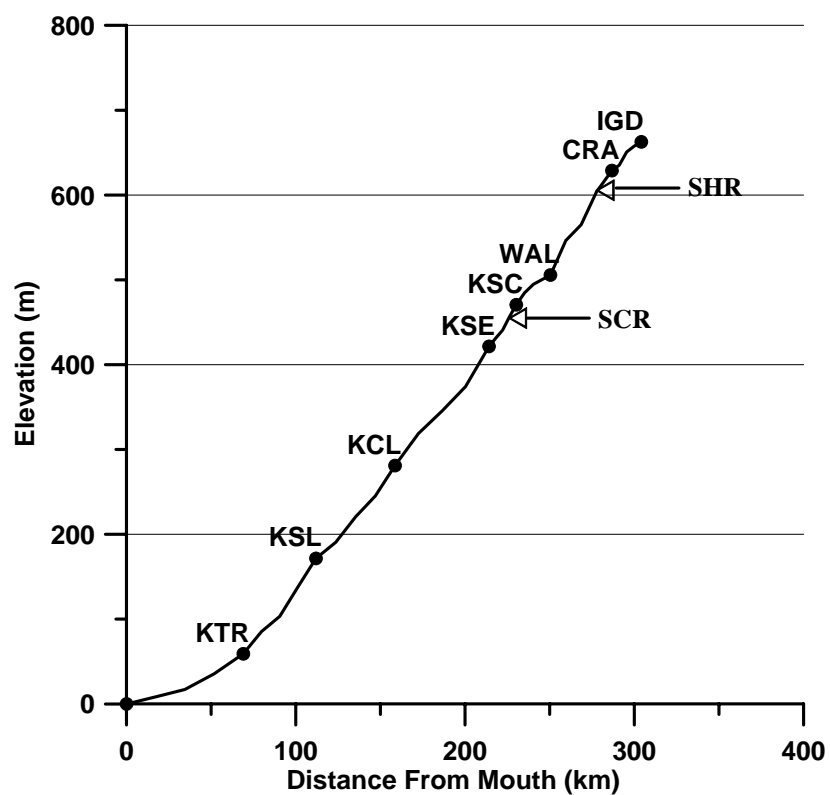


Figure 2. Location of sampling sites on the Klamath River with respect to elevation and distance from the mouth. Site codes are shown in Table 1.

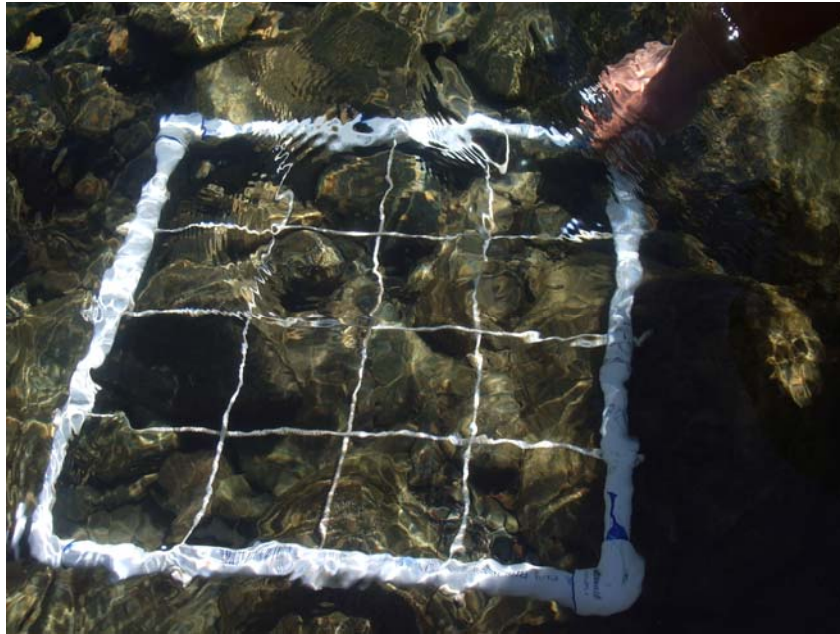


Figure 3. Example deployment of quadrat used for periphyton analysis in the Klamath River (shown in shallow water to illustrate the quadrat; typical deployment was in water 0.3 to 0.6 m in depth).



Figure 4. Four rocks removed from the Klamath River for various periphyton analyses. These rocks are from site WAL.



Figure 5. “Microscope slide” Delrin template used for scribing rocks to sample the periphyton quantitatively. This image is from site SHR.



Figure 6. Example of the scraped periphyton from a rock at site SCR.

RESULTS

The physical characteristics of the sample sites are summarized in Table 2. Photo-documentation of the sites is provided in Appendix A (Attached CD). The sites, as prescribed in the methods protocol, ranged from areas with depth from 0.3 to 0.6 m. Current velocity at the sites ranged from 0.3 to 0.55 m/s. Substrate at all sites consisted of cobble and rock. Light reduction at a depth of 0.3 m ranged widely from 20 to 75 percent (Figure 7).

The *in-situ* water quality data showed that dissolved oxygen concentrations were generally at or above 100% saturation and pH values ranged from 8.1 to 9 (Table 3). It is difficult to compare the temperature, dissolved oxygen, and pH results among sites because the sampling times ranged from 0830 hr to 1600 hr. Conductivity was near 130 $\mu\text{S}/\text{cm}$ for all sites, except for the Shasta River (SHR) where conductivity was measured at 337 $\mu\text{S}/\text{cm}$. ORP was positive and relatively low at all sites, but because of long equilibration times often required for ORP probes, these values are likely underestimates of the actual ORP.

Table 2. Attributes of study sites.

Site Name	Site Code	Date	Time	Velocity (m/s)	Depth (m)
Irongate Dam (tailrace)	IGD	9/1/04	1015	0.55	0.37-0.61
Klamath at Collier Rest Area	CRA	9/1/04	0830	0.53	0.3-0.61
Shasta River	SHR	9/1/04	1145	0.55	0.3-0.46
Klamath at Walker Bridge Rd	WAL	9/1/04	1315	0.42	0.38-0.46
Klamath Above Scott Creek	KSC	9/1/04	1600	0.40	0.3-0.46
Scott River	SCR	9/1/04	1425	0.31	0.3-0.34
Klamath at Seiad Valley	KSE	9/2/04	1600	0.45	0.3-0.61
Klamath Above Clear Creek	KCL	9/2/04	1400	0.32	0.3-0.38
Klamath Above Salmon River	KSL	9/2/04	1237	0.38	0.3-0.61
Klamath Above Trinity River	KTR	9/2/04	1100	0.31	0.3-0.61

Table 3. *In-Situ* water quality measurements collected during the periphyton survey.

Site Order	Site Code	Temp (C)	pH	DO (mg/l)	DO (%)	DO Winkler (mg/L)	Cond (μS/cm)	ORP (mvolts)
1	IGD	21.08	8.96	9.10	102.3	7.56	122	20.2
2	CRA	19.09	8.13	7.98	86.2	7.29	125	40.5
3	SHR	19.79	8.30	10.72	117.5	8.58	337	44.3
4	WAL	22.03	8.67	10.46	119.7	9.06	122	26.1
5	KSC	22.61	8.69	10.48	121.5	9.80	142	25.4
6	SCR	23.87	8.52	8.98	106.5	9.24	157	30.5
7	KSE	21.65	8.57	10.05	114.1	10.3	142	35.9
8	KCL	21.55	8.44	9.73	110.8	13.2 ^a	135	19.7
9	KSL	21.59	8.48	NA ^b	NA ^b	8.96	135	39.8
10	KTR	21.07	8.23	11.66	131.5	8.38	130	40.9

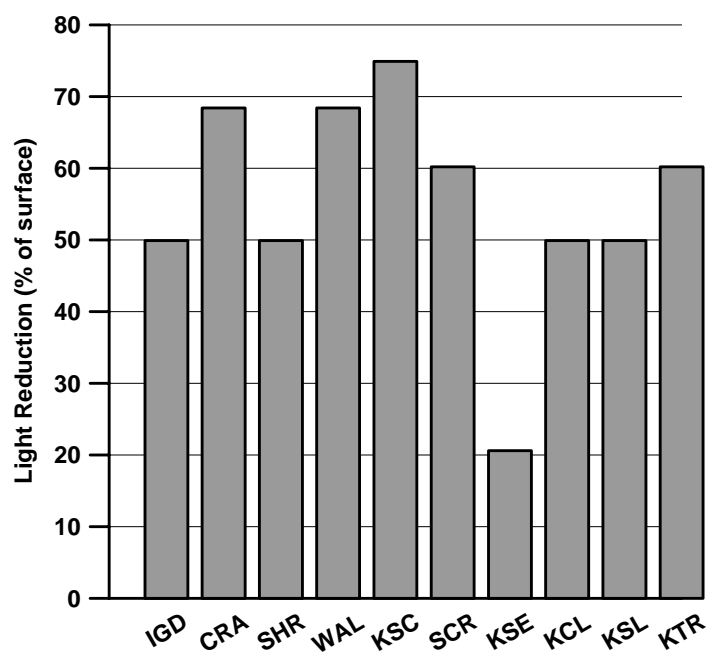
^a Switched titrants; Winkler DO is high^b NA: DO membrane ruptured.

Figure 7. Percent reduction of incident light for sites in the Klamath River system shown at a depth of 0.3 m.

The percentage of stream rocks with periphyton coverage ranged considerably among sites (Figure 8), but did not exhibit a strong correlation with either wet or dry weight of the periphyton samples (Figure 9). In this case it is understandable because many of the rocks were only covered with a thin coating of diatoms, whereas in streams with abundant macro-algae such as *Cladophora* one might expect a better relationship between percent coverage and mass. The periphyton dry weights were measured at both 105 °C and 500 °C (Figure 10). Both yielded reasonable measures of mass relative to wet weight, although the sample size is too small to adequately quantify these relationships. Dry weight measured at 105 °C retains some organic carbon in the samples, whereas dry weight measured at 500 °C results in complete ignition of all carbon.

The chlorophyll *a* content of the uniformly-scraped areas provides a recognizable pattern whereby the chlorophyll decreases radically between Iron Gate Dam (IGD) and the Collier Rest Area (CRA) and then increases in a predictable manner downstream (Figure 11). The species composition of the dominant taxa show there are some recognizable spatial patterns in the communities (Figure 12). The upstream periphyton is dominated by *Coconeis placentula* and *Diatoma vulgare*, which transitions to a periphyton community that becomes heavily dominated by *Epithemia sorex* (all diatoms). The two tributary sites show the most divergent periphyton communities with the Shasta River site (SHR) dominated by the green filamentous alga, *Cladophora*, and the Scott River totally dominated by the diatom, *Cymbella affinis*. The diatom, *Synedra ulna*, is abundant at a number of sites throughout the length of the study reach.

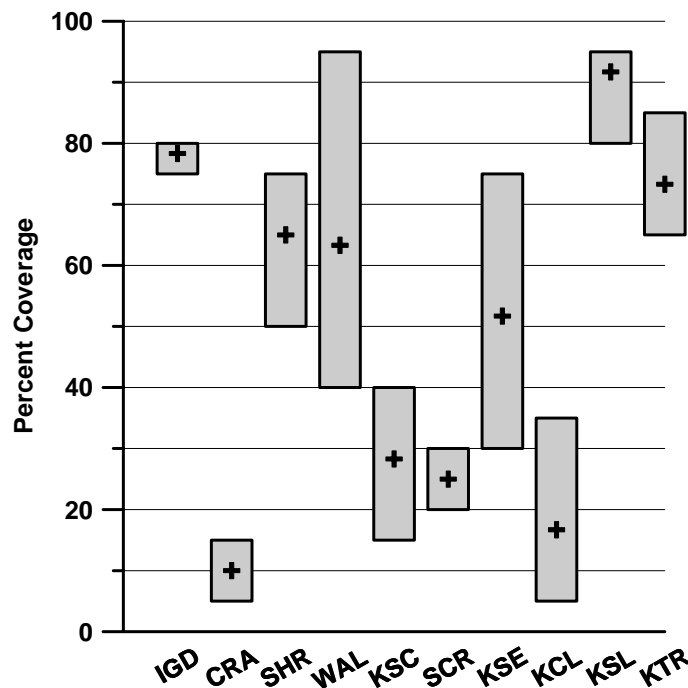


Figure 8. Range and average (+) periphyton coverage of rocks, based on three quadrat placements at each site.

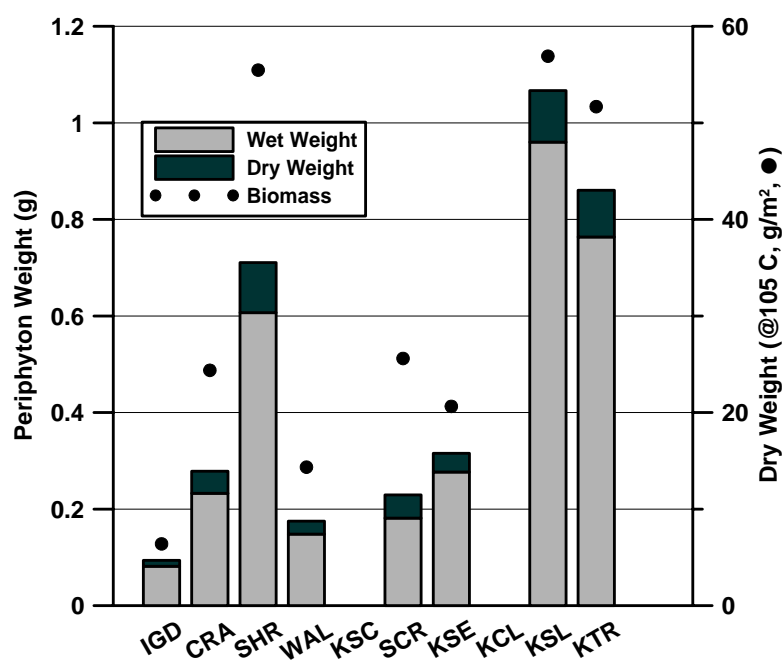


Figure 9. Wet and dry weight (105 °C) of sample sites in the Klamath River system. Sites KSC and KCL had insufficient sample size to quantify the mass of material. KTR_b was a duplicate; KTR_a had insufficient sample to quantify.

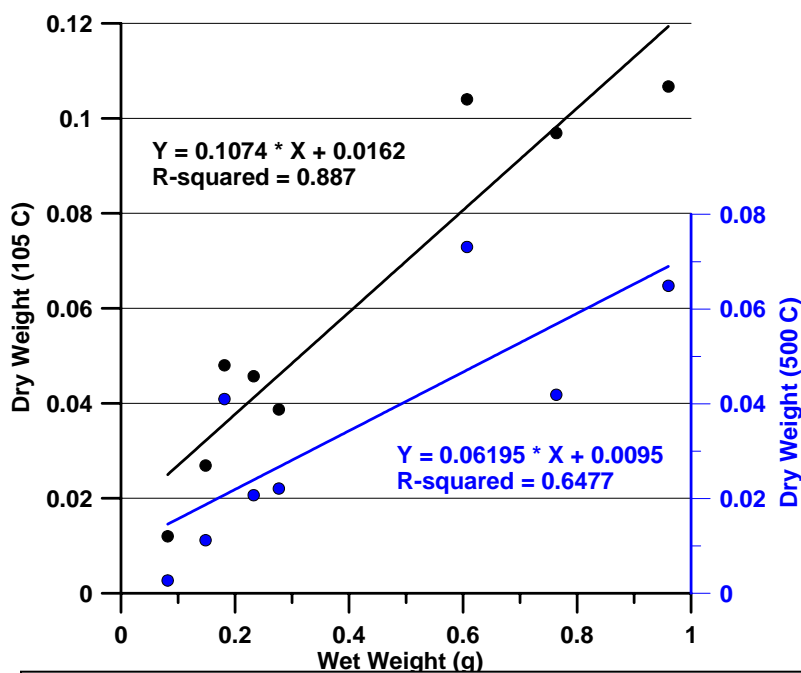


Figure 10. Linear regressions between wet weight and two temperature treatments of dry weight.

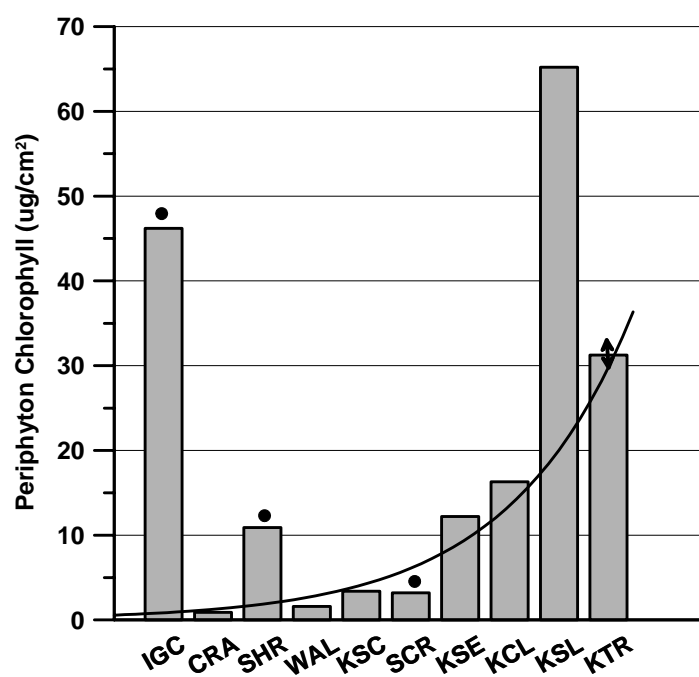


Figure 11. Chlorophyll content of periphyton samples in the Klamath River system. The curve is an exponential fit of chlorophyll to the mainstem sites, excluding site IGD.

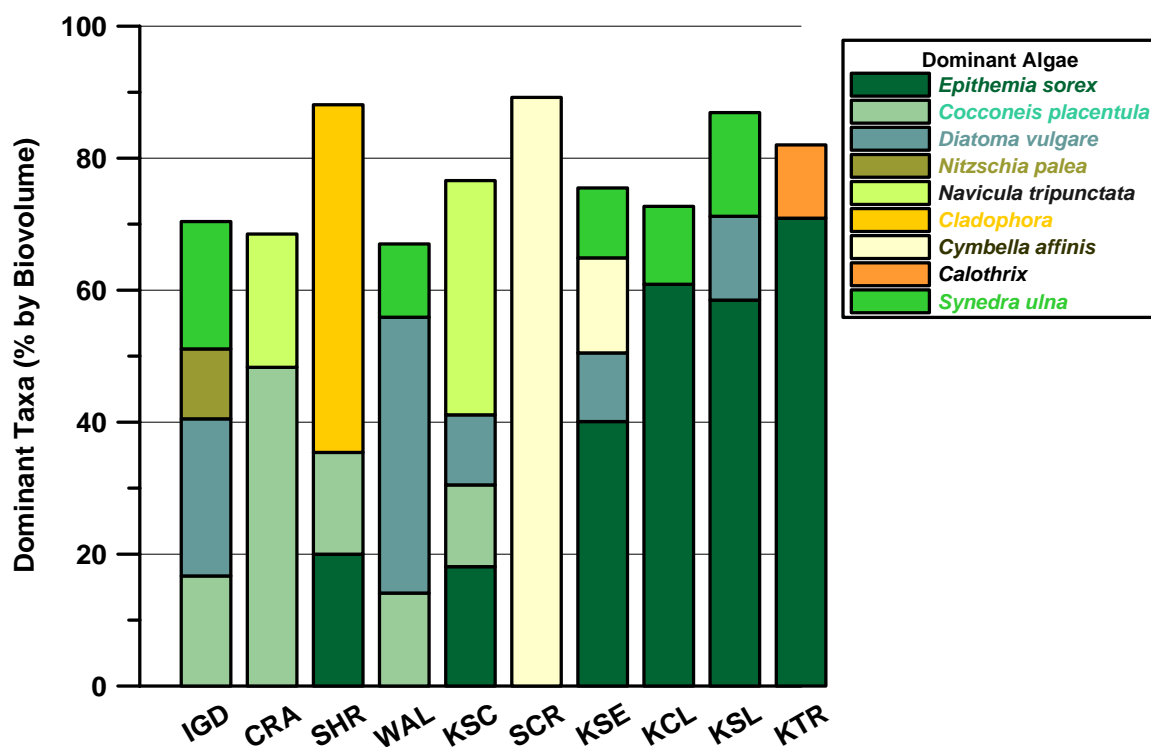


Figure 12. Dominant periphyton algal taxa at ten sites in the Klamath River system. Taxa with a relative abundance greater than 10 percent (based on biovolume) at any site were listed as dominant. A complete list of all taxa present in the samples is included in the database.

The periphyton exhibited a wide range of carbon, nitrogen and phosphorus concentrations among the study sites (Figure 13-15). However, the three nutrients are generally present in similar ratios resulting in an apparent pattern when plotted against distance from the mouth (Figure 16). As a consequence, the ratio of C:N and N:P are quite consistent among sites (Figures 17 and 18). The one major exception is for the Scott River (SCR) where the N:P ratio is extremely high.

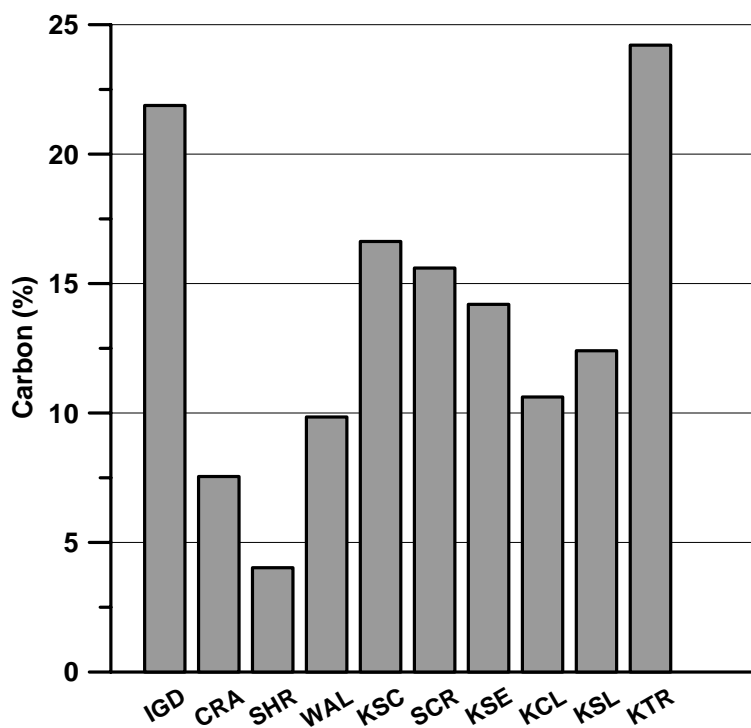


Figure 13. Percent carbon content of periphyton at ten sites in the Klamath River system.

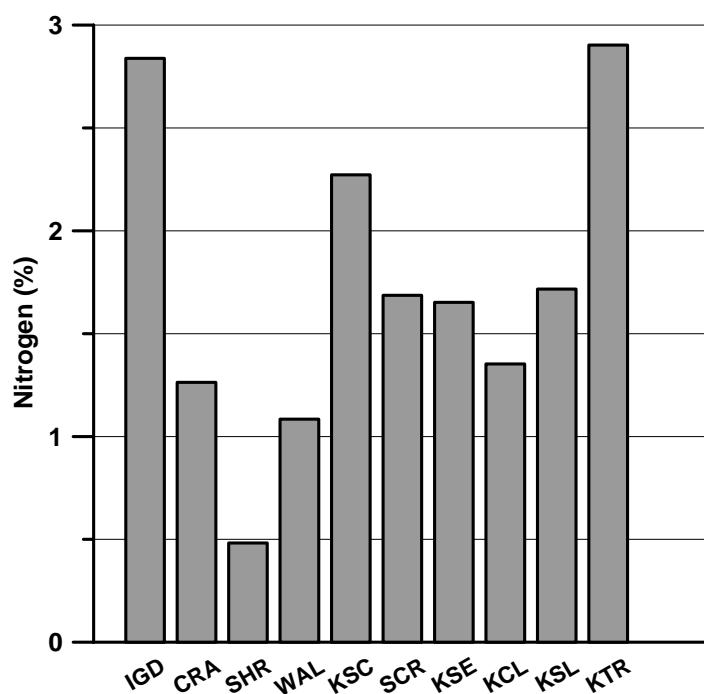


Figure 14. Percent nitrogen content of periphyton at ten sites in the Klamath River system.

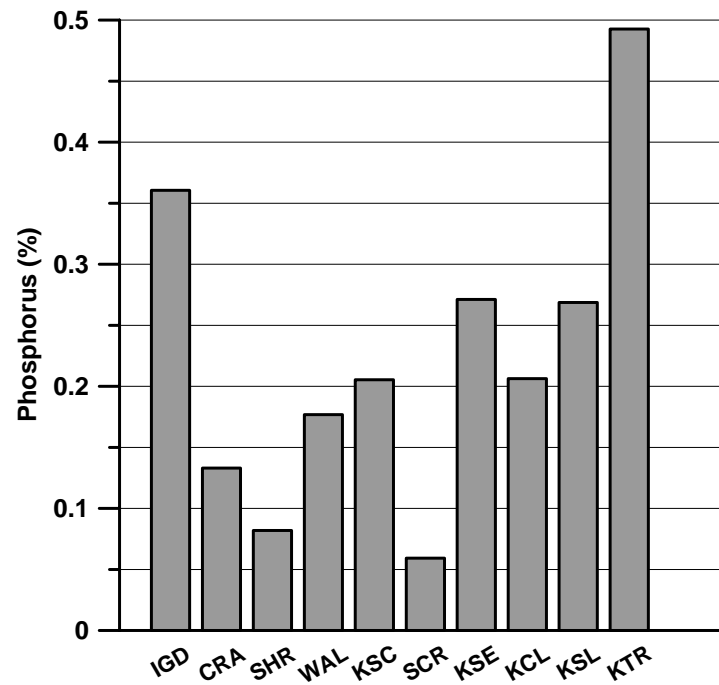


Figure 15. Percent phosphorus content of periphyton at ten sites in the Klamath River system.

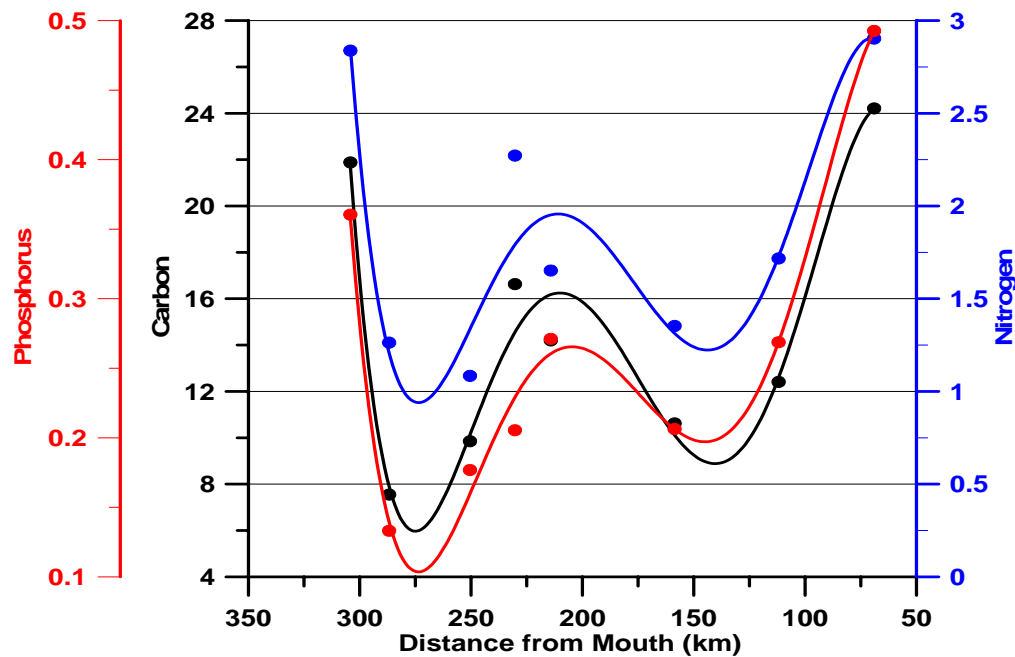


Figure 16. Polynomial fits of carbon, nitrogen, and phosphorus concentrations (all in mass units) for periphyton samples from the mainstem sites in the Klamath River plotted as a function of distance from the mouth.

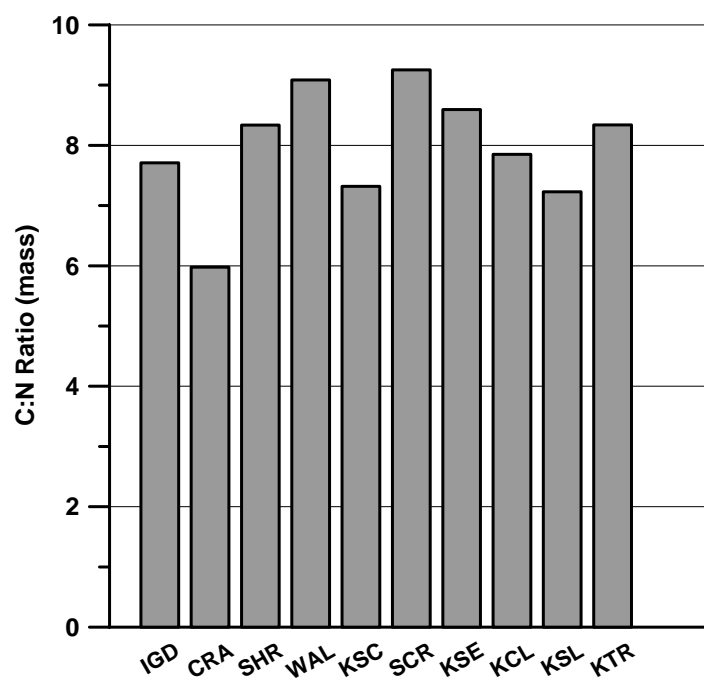


Figure 17. Carbon to nitrogen ratio (mass ratio) of periphyton at ten sites in the Klamath River system.

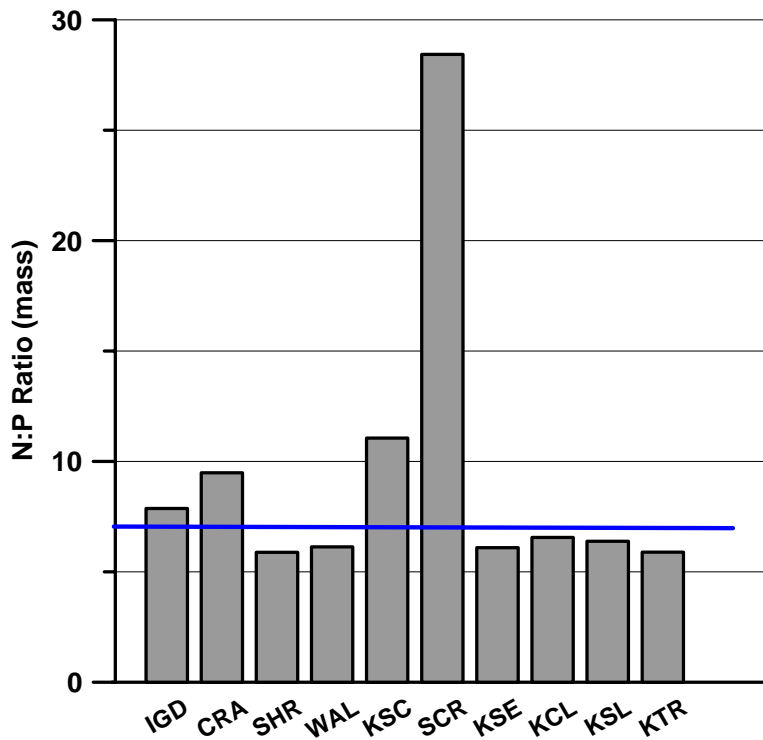


Figure 18. Nitrogen to phosphorus ratio (mass ratio) of periphyton for ten sites in the Klamath River system. The Redfield ratio (blue line) is shown for reference.

DISCUSSION

The sampling sites were designed to sample periphyton in similar habitats defined by depth, velocity, and substrate composition. The data reported in Table 2 indicates that this objective was achieved. Light reduction was insufficient to limit primary production at any of the sampling sites and thus factors other than light and physical habitat features were most likely responsible for differences in periphyton among sites. Chlorophyll *a* content varied from about 1 ug/cm² at the Collier Rest Area (CRA) site immediately downstream of the Iron Gate Dam to a high of over 65 ug/cm² at in the Klamath River above the confluence with the Salmon River (KSL). The second highest chlorophyll *a* values were measured immediately below the Iron Gate Dam (IGD).

The percentage of rocks covered with some degree of periphyton growth showed a weak relationship with chlorophyll *a* content of the sampled areas, despite the relatively good precision in the measurement of percentage periphyton coverage. The mass (wet and dry weights) of periphyton at the sites showed moderate agreement with the chlorophyll *a* content of the samples with the major exception of the low periphyton mass at IGD relative to the chlorophyll content.

The biomass of periphyton on the rocks was generally low to moderate, which was not in keeping with our expectations prior to the survey. Although it is not possible to conclusively attribute a cause for this modest level of periphyton in the Klamath River, it is possible that changes in flow regime immediately before the September survey may have altered the density of periphyton. About one week prior to the September survey, flow releases from Iron Gate Dam nearly doubled from flows that had been held low and stable for the previous month (Figure 19). This increase in discharge with the accompanying increase in stream velocity may have been sufficient to dislodge filamentous algae that had proliferated under the low-flow regime. Although no sloughing of algae was observed during our study, the duration between the onset of the increased discharge and our survey would have been sufficient to transport the material to the mouth by the beginning of the sampling.

The dominant periphyton taxa at the sampling sites showed some striking distributions. In the five upstream sites, *Cocconeis placentula* and *Diatoma vulgare* were the dominant diatoms. This dominance gave way to dominance by *Epithemia sorex* in the downstream sites. The transition from *Cocconeis/Diatoma* to *Epithemia* was marked by a strikingly uniform population of *Cymbella affinis* in the Scott River (SCR). Remnants of this *Cymbella* population are evident in the mainstem Klamath River sites immediately downstream of the Scott River (KSE). The only site with a significant growth of the filamentous green alga, *Cladophora*, was the Shasta River where it represented one-half of the periphyton community (by biovolume). *Cladophora* is often present in streams with enriched nutrient loading. A modest population of *Synedra ulna* was present

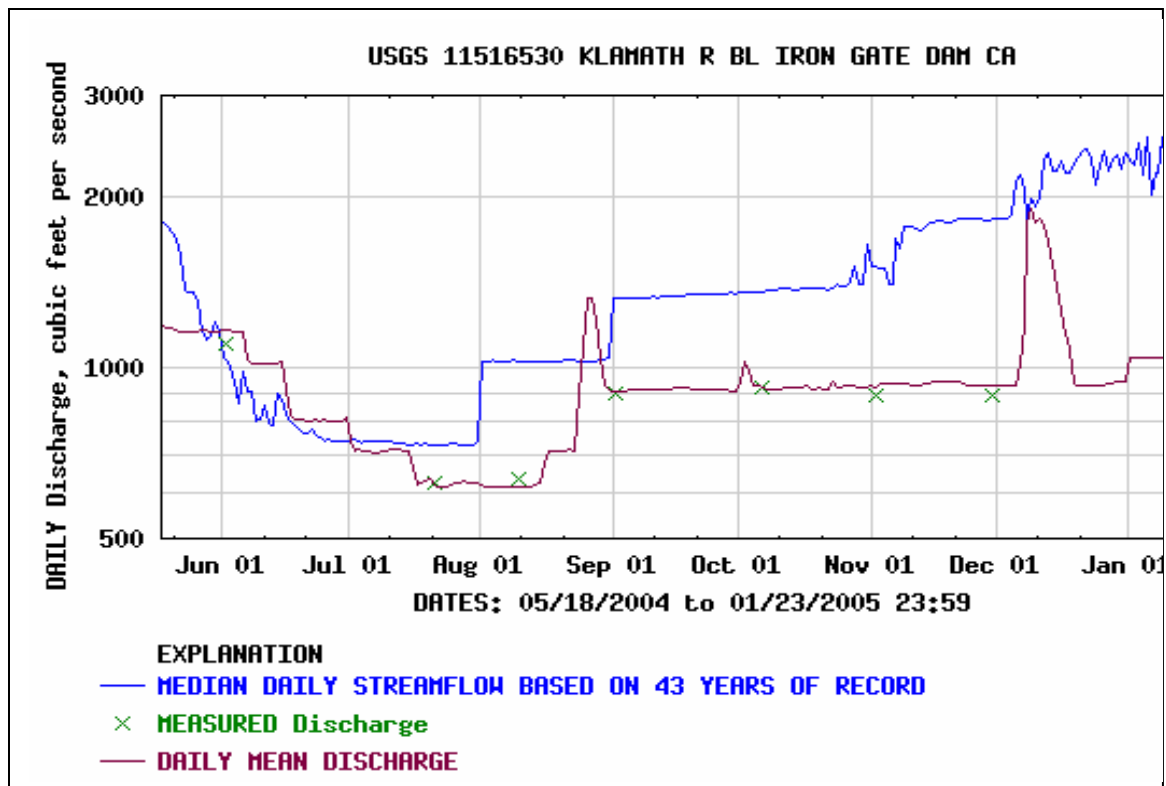


Figure 19. Stream discharge in the Klamath River below Iron Gate Dam from May 15, 2004 to January 10, 2005. (Source: USGS, daily streamflow measurements).

throughout the mainstem sites. The most downstream site (KTR) was the only site with a significant amount of filamentous cyanobacteria (*Calothrix*) present.

Epithemia sorex is often associated with lower elevation streams with abundant filamentous green algae (such as *Cladophora*), somewhat elevated conductivity and nutrients (Lowe 1974; Patrick 1977, Bahls et al. 1984). Bahls (1993) considered *Nitzschia palea* to be indicative of pollution in Montana streams, but considered *Epithemia sorex* to be highly sensitive to pollution disturbance. Blinn and Herbst (2003) ranked *Cocconeis placentula* the 3rd most pollution tolerant algal taxon among 63 taxon examined in the Lahontan Basin and *Epithemia sorex*, *Rhopalodia gibba* (another common taxon in the Klamath periphyton communities), and ranked *Nitzschia palea* in the upper quartile of pollution tolerant taxa. Palmer (1980) considered *Cymbella affinis* and *Synedra ulna* as important indicators of water pollution.

The periphyton community was one not atypical of montane and submontane streams in the western United States (Blinn and Herbst 2003; Bahls 1993, Lawrence and Seiler 2002) and elsewhere (Kawecka et al. 1971). *Cocconeis placentula*, *Diatoma vulgare*,

Nitzschia palea, and *Synedra ulna* are species often found in submontane and lower valley sites where nutrient enrichment contributes to their prominence (Blinn and Herbst 2003; Lawrence and Seiler 2002). The most unusual periphyton community sampled was the dominance of *Cymbella affinis* in the Scott River (SCR). This distribution is addressed again following the review of the periphyton chemistry results.

The periphyton exhibited considerable ranges in the concentrations of carbon, nitrogen, and phosphorus, with the lowest concentrations found in the Shasta River site (SHR) and the highest concentrations found at both ends of the study transect (IGD & KTR). The concentrations of all three nutrients are highly synchronous in the mainstem sites leading to similar ratios of C:N and N:P in the mainstem sites. It is unclear whether the pattern observed in Figure 16 is indicative of a robust ecological pattern considering that this survey consists of a small number of sites during one sampling event. However, it may indicate a spatial reallocation of nutrients associated with inputs from the Iron Gate Reservoir followed by uptake and renewed inputs of nutrients from tributaries.

The most dramatic case of nutrient shifts among the study sites is evident in the N:P ratios measured at the Scott River (SCR) where the mass ratio was about 28 compared to a typical value of 6 to 8 observed at most of the other sites (Figure 18). A ratio this high is generally associated with phosphorus limitation, which is consistent with the low phosphorus concentrations measured at SCR. This radical departure in the N:P ratio at SCR may explain the almost total dominance of *Cymbella affinis* at this site (Figure 12). This diatom taxon may be efficient in low-phosphorus environments or it may be responding to the comparatively high nitrogen availability.

This brief examination of the periphyton community in the Klamath River system suggests that there are some major changes in the periphyton community that appear to be controlled to some degree by differences in nutrient availability. However, we have not factored in other possible issues such as antecedent flow conditions or differences in periphyton grazing rates.

In summary, the periphyton populations observed in the September 2004 sampling of the Klamath River system exhibited low biomass and was dominated by taxa typically found in moderately enriched submontane riverine systems. The species composition showed a transition from a *Cocconeis/Diatoma*-dominated community upstream to a system heavily dominated by *Epithemia* downstream. The nutrient concentrations of the periphyton showed large ranges in concentrations, but relatively constant ratios of C:N and N:P, the one major exception being the Scott River where the N:P ratio was four-fold greater than the average river ratio. The high N:P ratio in the Scott River coincided with a totally different periphyton community dominated by *Cymbella affinis*.

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APPENDICES

Digital images of the sample sites are provided on a separate CD.